Dialogues of Civilization 2018 - Biomedical Imaging
Homework 3

Due date: 6/6/2018

Please solve the following problems and email the solutions to *kercher.e@husky.neu.edu.*

1 MRI Basics

(a) Calculate the gyromagnetic ratio γ (in MHz / T) and the Larmor frequency ω (in MHz) for each of the three primary sub-atomic structures: proton, neutron, and electron. Assume a $1.5T$ magnetic field. Discuss the feasibility of using each of these sub-atomic particles in MRI.

Table 1: Properties of subatomic particles

	Mass [kg]	g-factor
proton	9.11E-31	+5.6
neutron	1.67E-27	-3.5
electron	1.67E-27	-2.0

(b) The majority of hydrogen atoms found in the body are contained in water and fat. The chemical shift of ^1H between water and fat is approximately 3.5 ppm. Calculate the difference in signal frequency between the two substances in a 1.5T and 3T imager.

(c) A phantom containing two pools of water is measured in a 1.5T imager. A 2 G/cm frequency encoding gradient is applied along the x-axis. The measured NMR spectrum contains frequencies of +900 Hz and -400 Hz relative to isocenter. Find the locations of the two pools of water.

2 MRI Images

Browse `www.mridata.org` and pick a data set to explore for this problem. Download the zip file under "Acquired Raw Kspace Data ". Be careful, these data sets can be quite large so make sure you have good wifi. You will also need to copy and save the accompanying Matlab function `readReconData` to be able to load the data into Matlab.

(a) Get to know your data set a little. Browse the header files and find the following info about your data set.

- x, y, and z resolution
- x and y field of view
- TR and TE

From the resolution and FOV, calculate the dimension of each voxel in the image.

(b) Use `readReconData` to load the data set into Matlab. Your data should load into one variable of class: 4D complex double. Determine the size of your data set, what is the meaning of each dimension?

(c) Now take an inverse Fourier Transform to convert your k-space data into an image. Pick a z-slice and plot it using `imagesc`. Then average together all channels from your data set, plot it next to the first image.

(d) The Signal to Noise Ratio (SNR) can be defined as $SNR = <S>/\sigma$, the mean signal devided by the variance of the image. Calculate the SNR for the two images from part (c). Which image has the best SNR? How does SNR depend on the number of channels? (**Hint:** Create a few images by averaging a varying number of channels (1, 2, 4, 8,...). Then plot SNR as a function of N and look at the relationship.)

(e) In theory, MRI images can be taken in any plane/3D volume relative to the B_0 field. However, we usually look at images in 3 primary planes defined by the body: Sagittal, Coronal, and Transverse (Figure 1). Pull out a slice from your data in each of these planes and plot them in the same figure. (**Hint:** The matlab demo below will show you how to properly adjust for different x-y-z resolutions.)

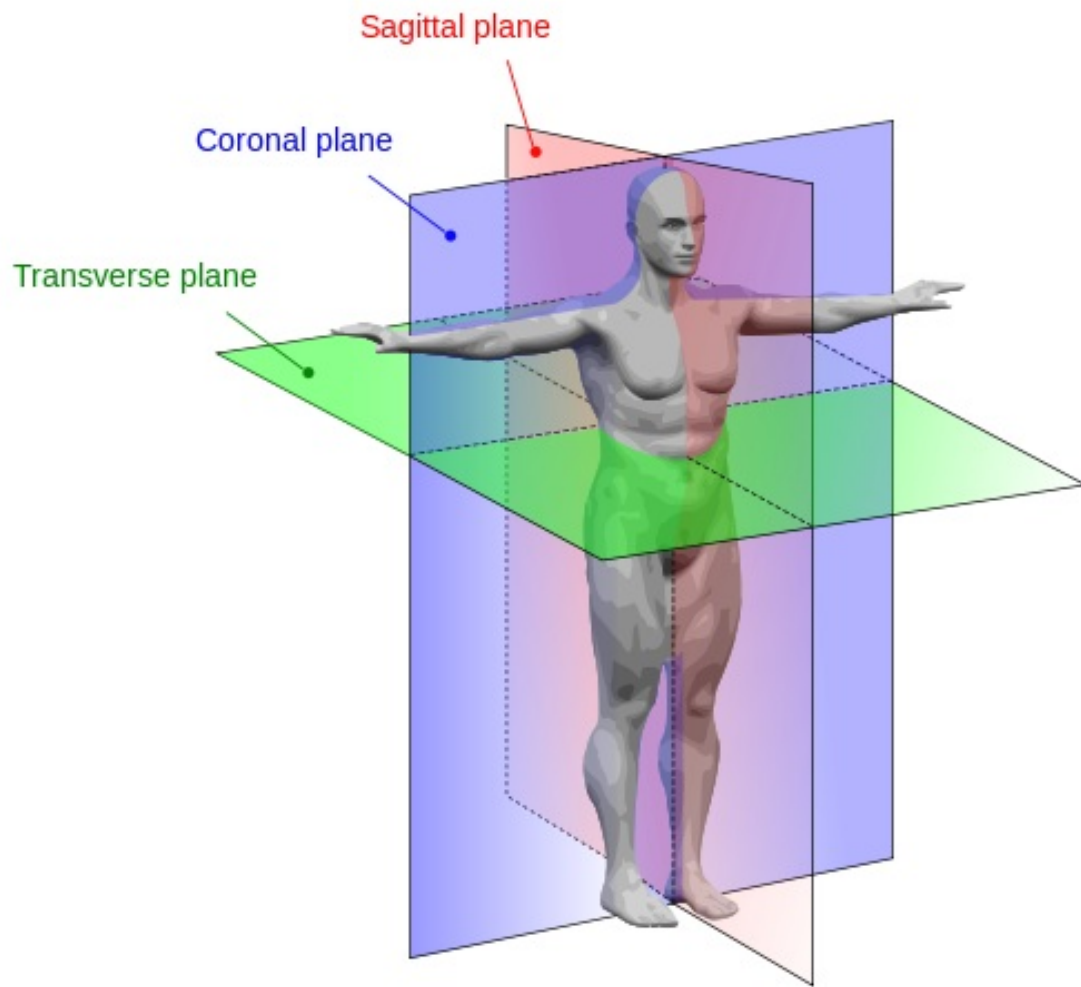MRI Image Slice Demo: https://www.mathworks.com/help/images/examples/exploring-slices-from-a-3-dimensional-mri-data-set.html

Figure 1: Three primary imaging planes.